Strip-Line Analysis

P. Murat A. Prem

July 30, 2012

Timing Resolution across Strip-Line Board

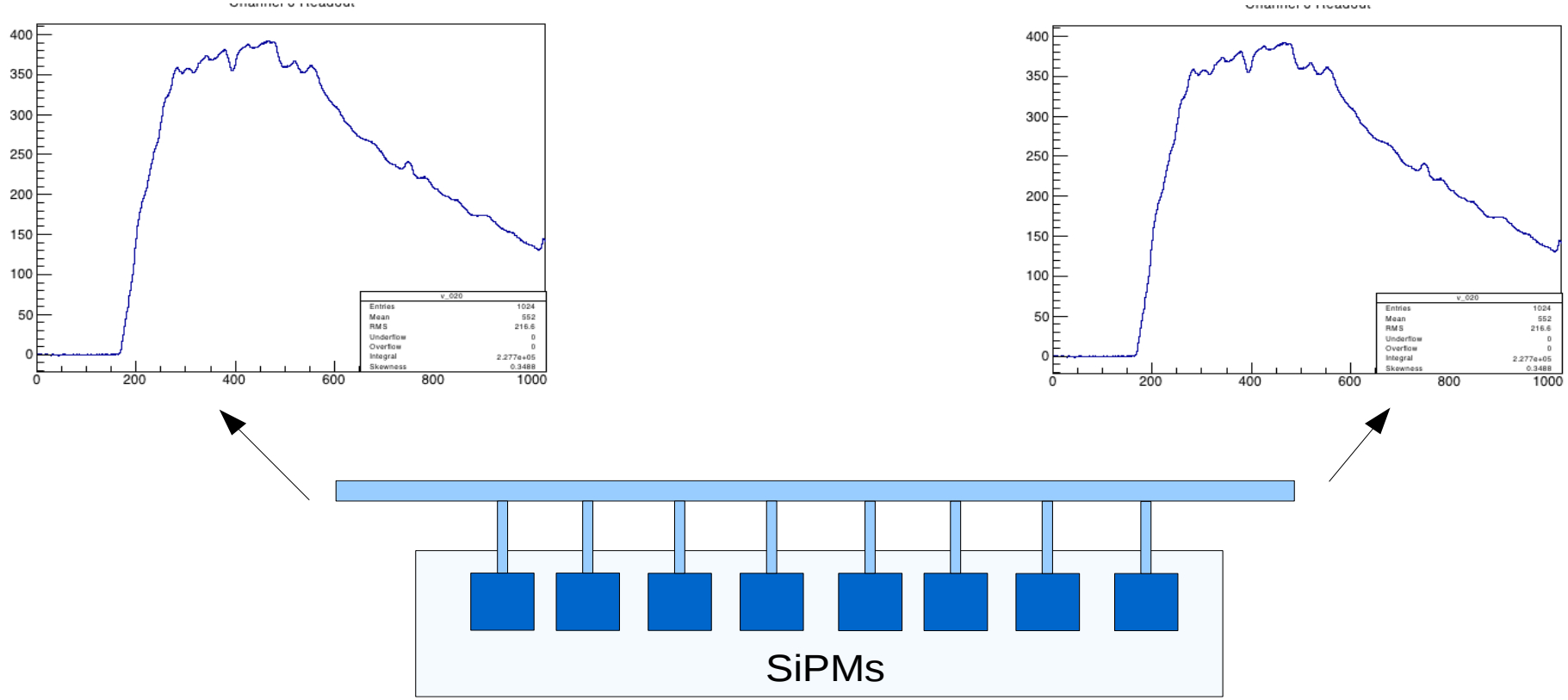

Figure: Strip Line Readout

- Pulse shapes only linear in small region.
- Linear fit procedure can use $\sim$ 2-35% part of leading edge, limiting the timing resolution.

Timing Resolution across Strip-Line Board

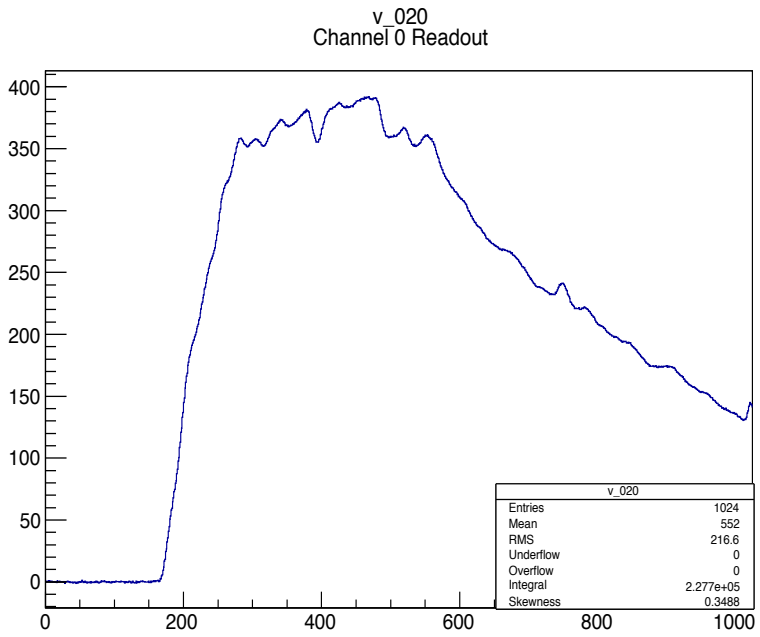

Figure: Channel 0

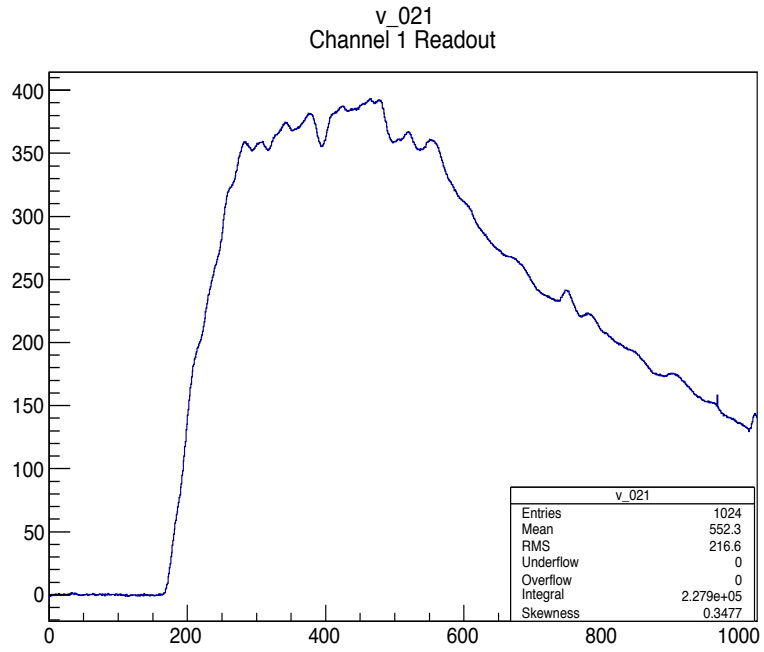

Figure: Channel 1

- Strip-Line read out from two ends: Ch 0 and Ch 1
- Data driven fitting procedure.
  - Normalize both pulses to $V_{max} = 1$.
  - Fit function: interpolated pulse in one of the channels, fit - shift of the function.
  - Δt comes directly from the fit.
  - No assumptions made about the pulse shape.
- For individual events, the pulse shape is not distorted as it propagates across the strip-line.
- Can now utilize $\sim$ 2-70% of readout data for fitting.

Fit Method

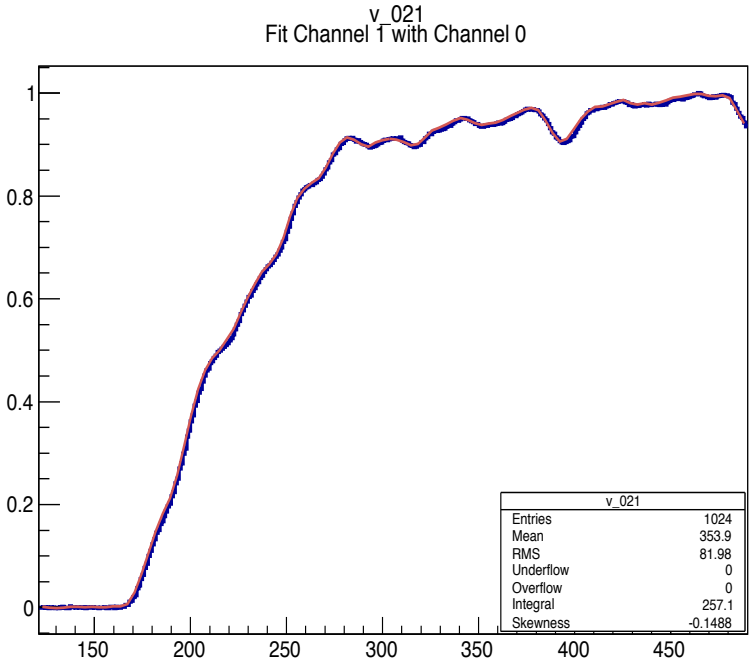

Figure: Fit Ch 1 Readout with Ch 0 Shape

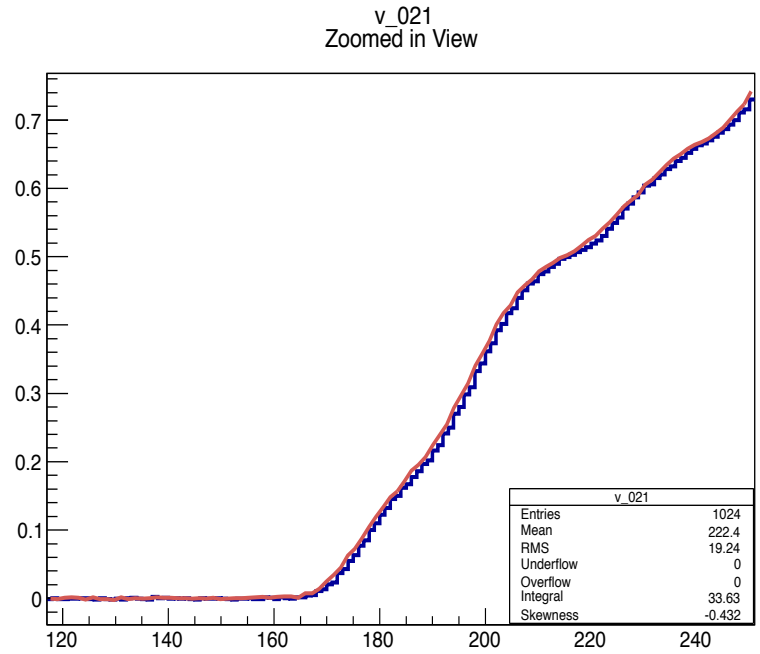

Figure: Zoomed In

- Pulse shapes readout from diff. channels for single events differ only by horizontal movement.
- Fit Ch 0 using a local parabolic interpolation.
- Extract this function and use to fit the readout from Ch 1.
- Horizontal shift gives us the timing difference across strip-line.

$$\Delta t = T[2] - T[1] \tag{1}$$

Energy distribution

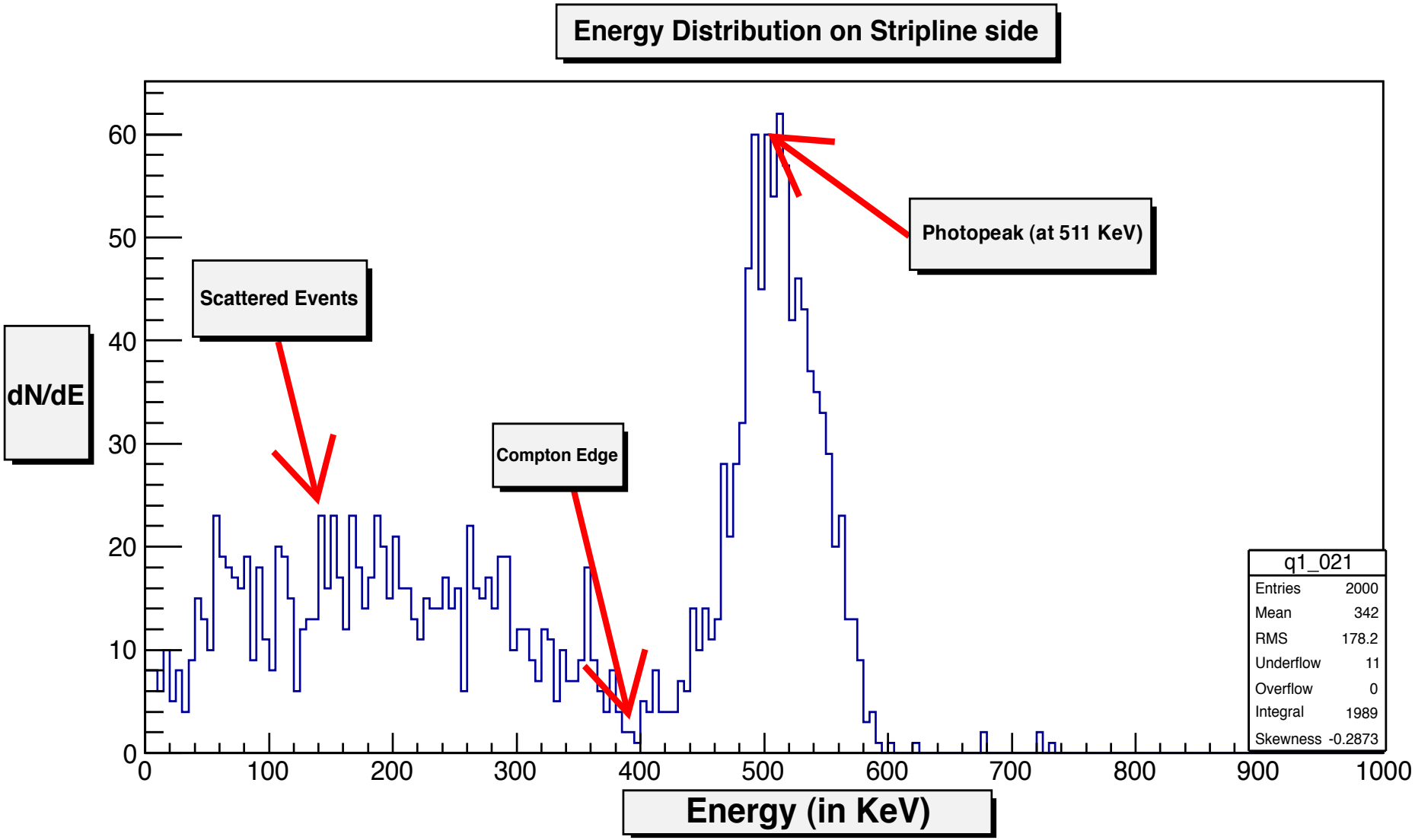

Figure: Energy Distribution

Results

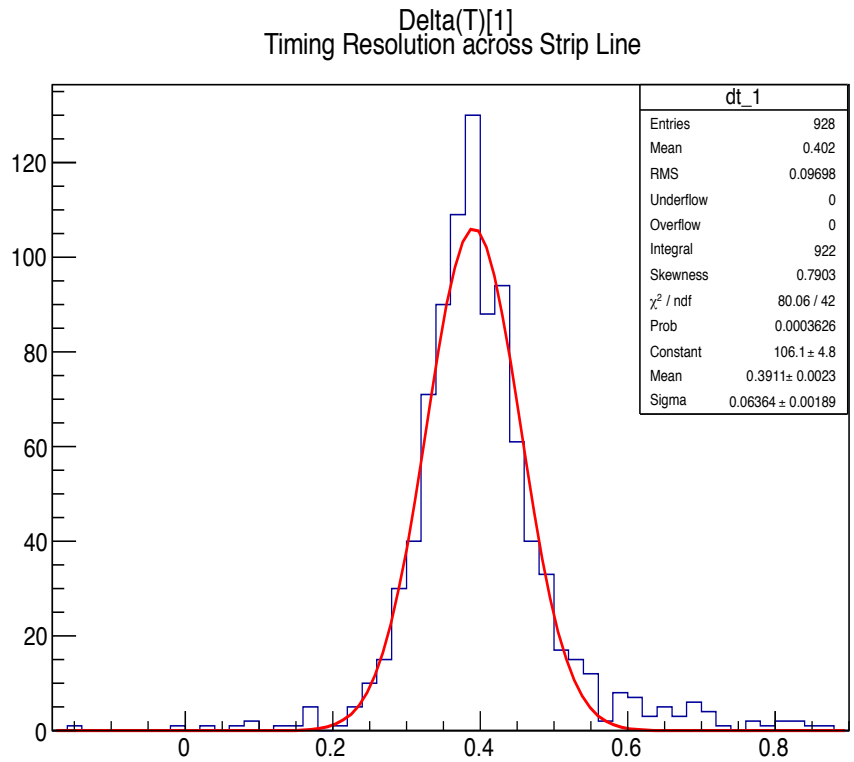

Figure: Δt(Channels)

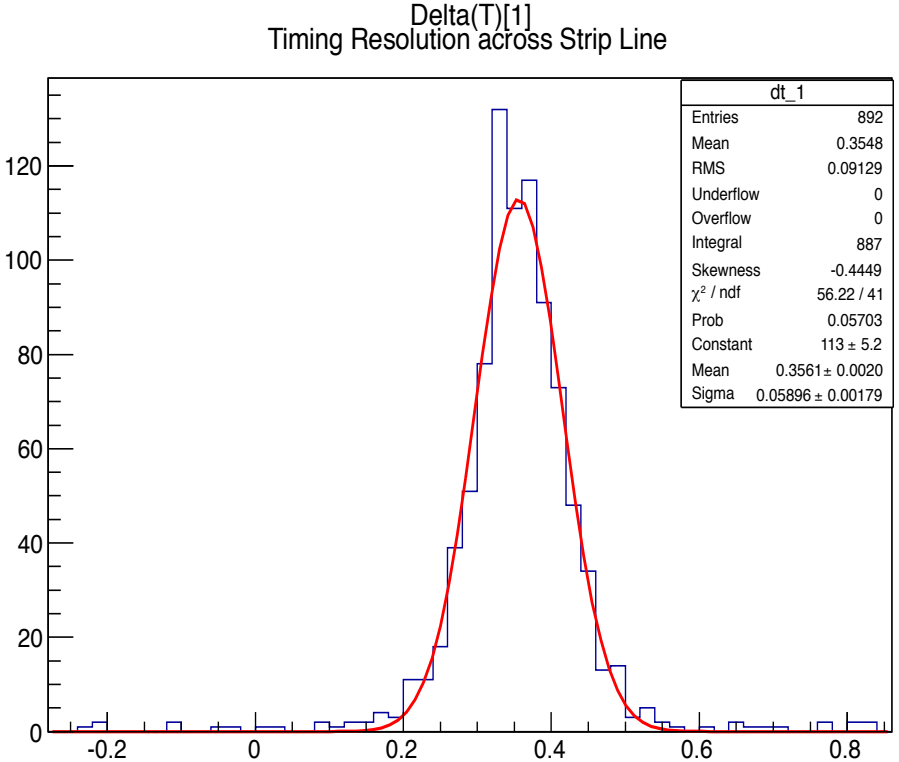

Figure: Δt(Channels)

- These are histograms of Δt from two different SiPMs, where Δt is given by the horizontal fit parameter.
- Only events from the photopeak are used in determining the timing resolution.
- For Figure 1: σ = 0.06364 (in channels) $\Longrightarrow$ FWHM = 30 ps.
- For Figure 2: σ = 0.05896 (in channels) $\Longrightarrow$ FWHM = 28 ps.

Results(contd.)

- StripLine with 8 SiPM's separated by 5mm
- Resolution (FWHM) along strip line(in ps):
- SiPM #1 : 33.37
- SiPM #2 : 28.20
- SiPM #3 : 50.57
- SiPM #4 : 61.52
- SiPM #7 : 44.68
- SiPM #8 : 31.46
- SiPMs #5 & #6 non-functional.

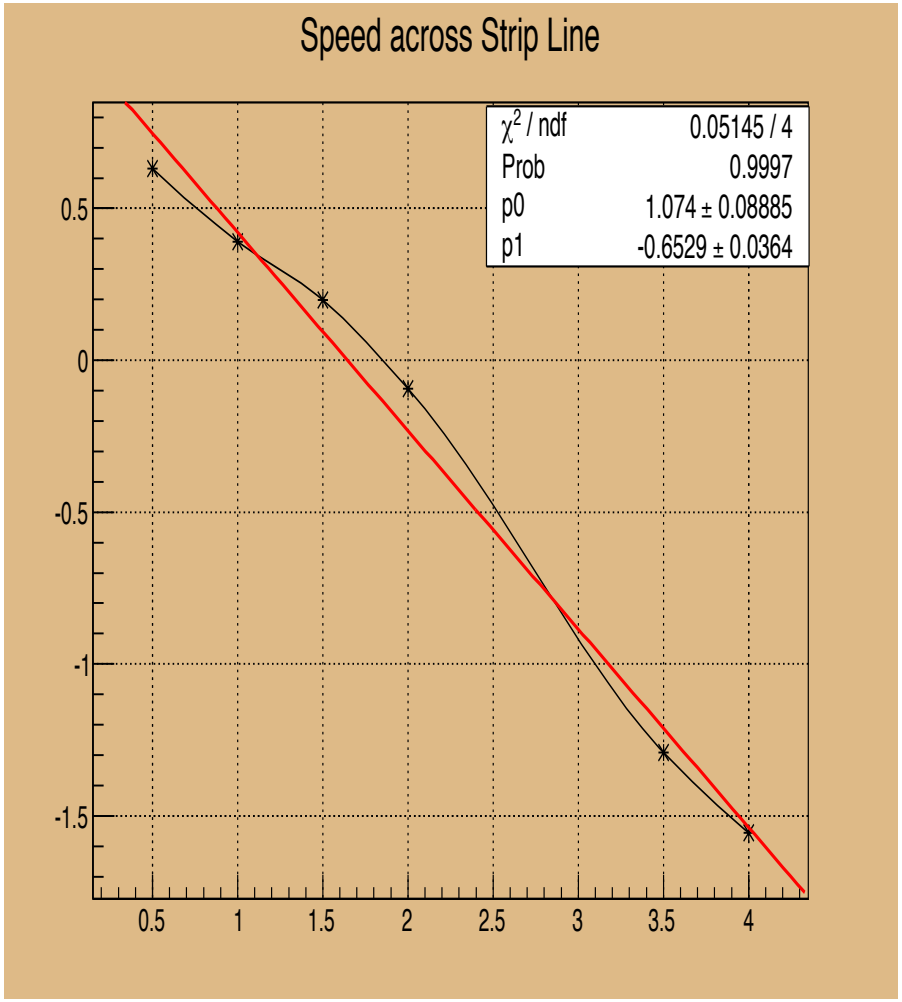

Figure: Δt Peak position (channels) vs SiPm position (in cm)

Preliminary Conclusions

- Heejong reported 36 and 38 ps for the stripline with 8 SiPMs.
- Thus, by using a data driven fitting procedure,we were able to improve timing resolution across the strip board by $\sim$ 18%
- Across the stripline (length = 35mm), measure speed of pulse $\sim$ 0.52c
- $$\Delta X = \frac{\Delta t \cdot c}{2} \tag{2}$$
- Using best timing results,this translates to a resolution of $\sim$ 2.2mm across strip line.

Investigating Non-Uniform Timing Resolution

- Noted significant non-uniformity in timing resolutions: SiPM #2 - 28 ps and SiPM #4 - 60 ps.
- To determine whether property of strip-line or SiPM's, swapped positions of 2 & 4.
- Results after swapping (FWHM):
  - For #4 (earlier #2) - 27 ps (earlier 28.2 ps)
  - For #2 (earlier #4) - 57 ps (earlier 61.5 ps)
- Since this agrees with previous data, it suggests dependence on SiPM's and also that pulse is stable across the strip-line.

Dependence on Bias Voltage

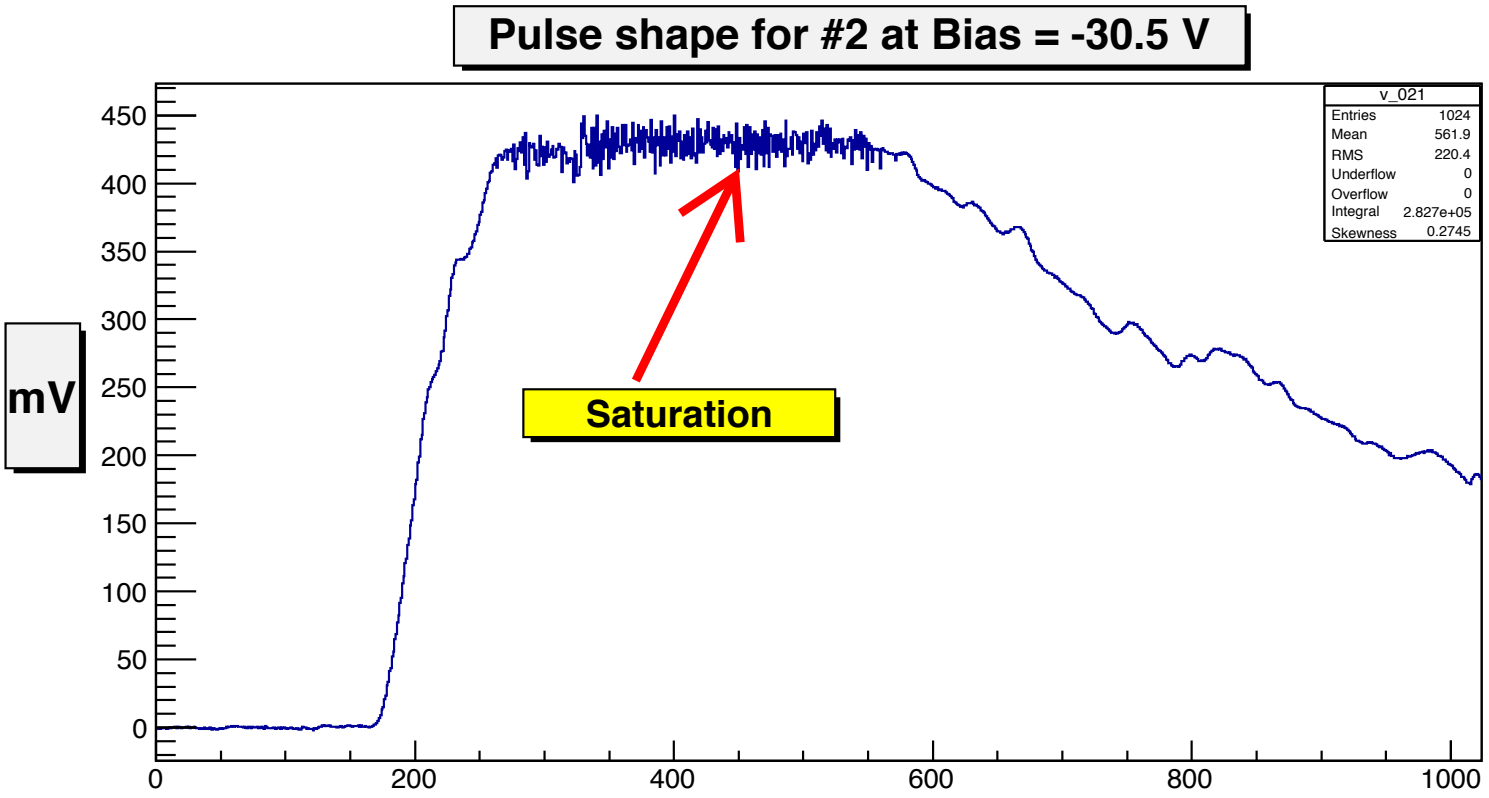

Figure: Saturation of SiPM

- Pulse Height depends on Bias Voltage.
- If pulse height $>$ 460 mV, indicates saturation of SiPM.
- SiPM's respond differently to bias: at -30.5V, SiPM #2 saturates while SiPM #4 does not.
- For fitting, the pulses are first normalized such that max. value of pulse height, $V_{max} = 1$. For saturated pulses, there are multiple maxima and this distorts the pulse shape on normalization.

Dependence on Bias Voltage (contd.)

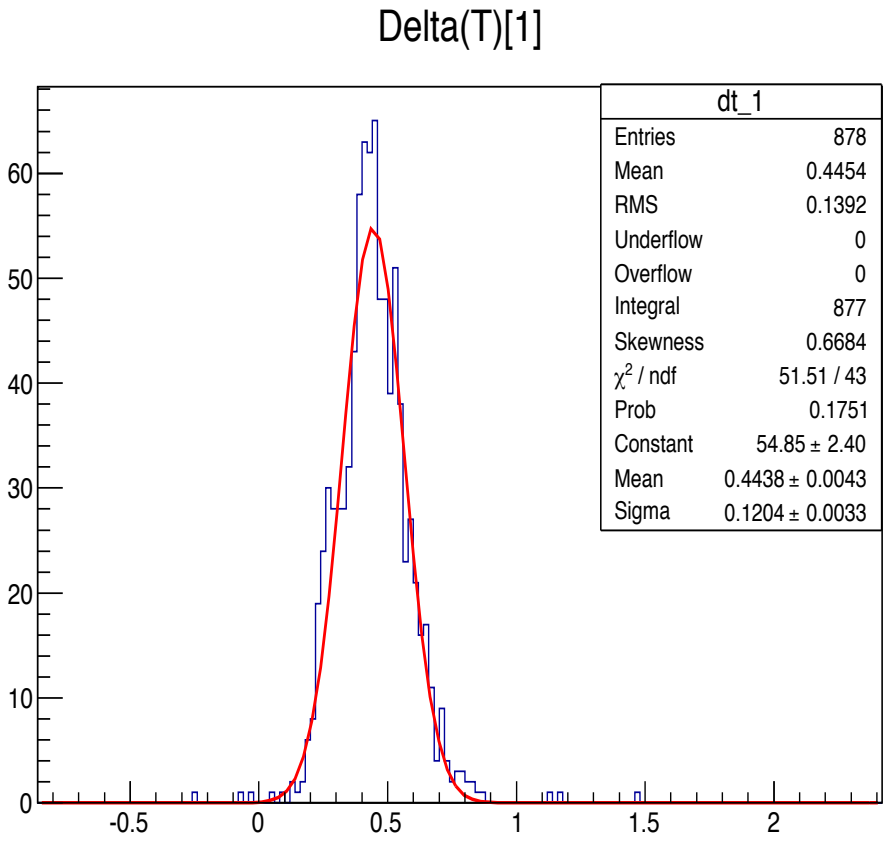

Figure: B.V = -30.5V

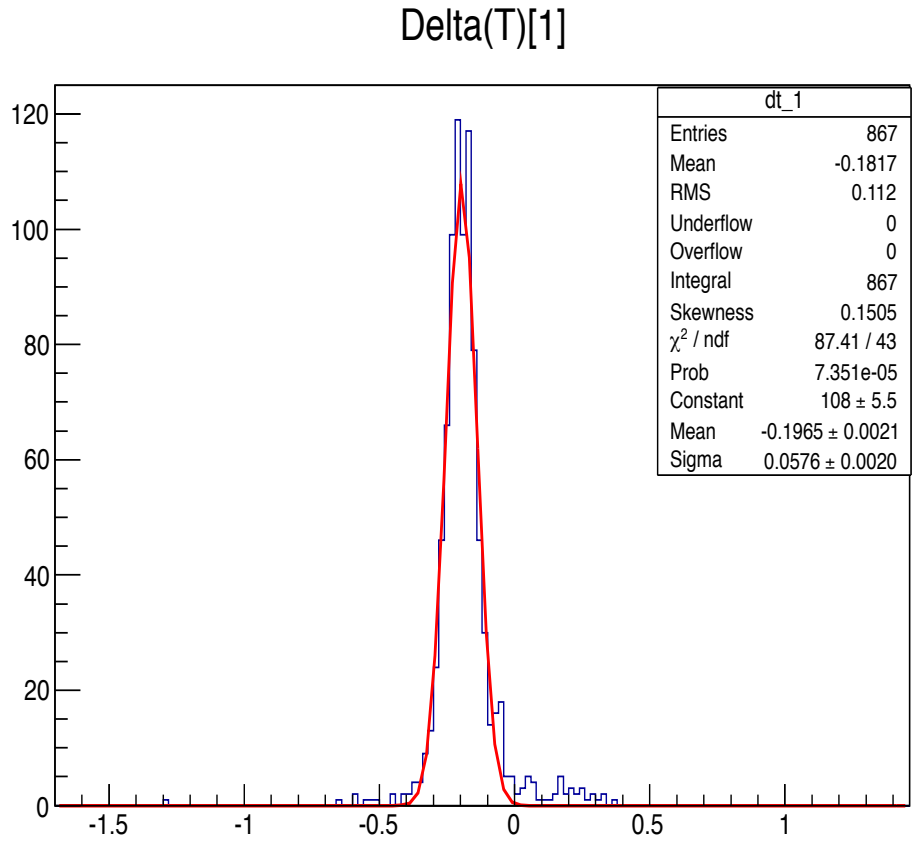

Figure: B.V = -30.0V

- Reduced bias voltage to avoid saturation, while also maximizing pulse height.
- Timing Resolution (FWHM) for SiPM #2 :
  - At -30.5 V: 56 ps.
  - At -30.0 V: 30 ps.
- So improved resolution by a factor of 2 using this procedure.

Effect of Pulse Height

- Repeated the same procedure - maximize pulse height while keeping below the saturation limit - for the other SiPMs. Resolution in FWHM:
- SiPM #1 : 33 ps (earlier - 33)
- SiPM #2 : 30 ps (earlier - 56)
- SiPM #3 : 28 ps (earlier - 51)
- SiPM #4 : 27 ps (earlier - 28)
- SiPM #7 : 46 ps (earlier - 45)
- SiPM #8 : 33 ps (earlier - 32)
- SiPMs #5 & #6 non-functional.
- Thus, the results are significantly more uniform now.
- For SiPMs #1 & #8, we expect resolution to be less than that of SiPMs in the middle, as pulse deterioration increases with increasing distance from the centre of the Strip Line.
- For SiPM #7, given that resolution for #8 is better, we suspect it is probably the SiPM that is responsible for the decreased resolution.

Effect of Pulse Height(contd.)

- Increasing the Pulse Height improves resolution significantly.
- The pulse shape itself is negligibly changed, apart from a scaling factor, and the leading edge (which is used for fitting) is also unchanged.
- The resolution improves linearly with increasing bias voltage.
- This suggests that at the level of $\sigma \sim 15$ps, the noise due to amplification becomes relevant and so when the bias voltage is increased (and so also the pulse height), this noise is pushed into the background.

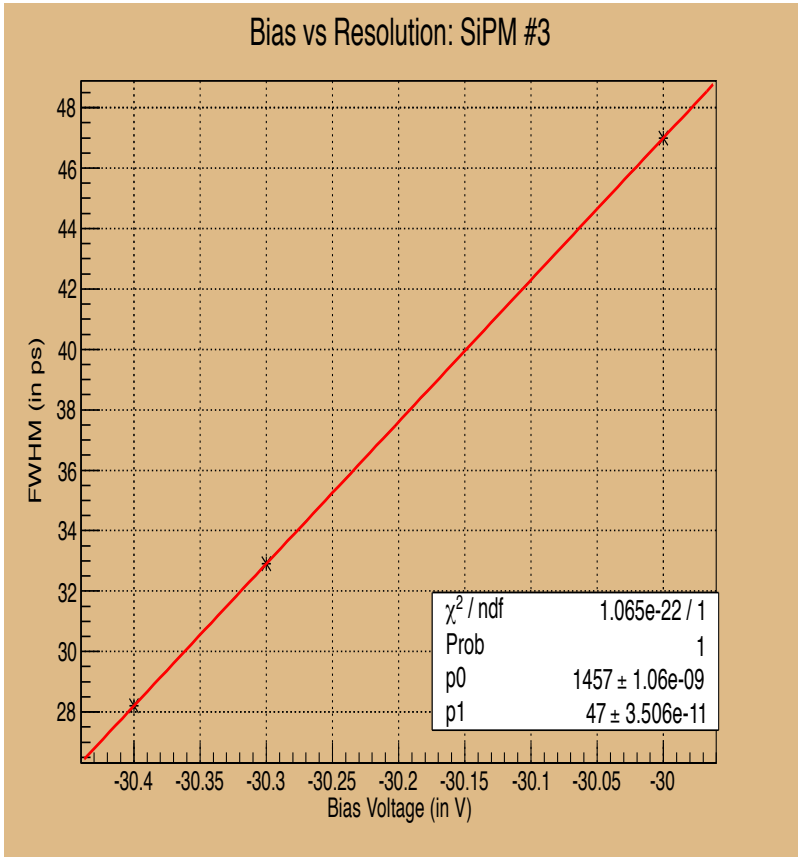

Figure: Linear dependence of Resolution on Bias

Conclusions

- Main Results:
  - Resolution of 30ps FWHM reproducible.
  - 2.2 mm across stripline board.
  - For outer SiPMs, resolution degrades by $\sim$ 20%
- Linear dependence on the overvoltage indicates that the resolution is driven by the electronic noise.